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Research and Development Technical Report
ECOM-0075-F

DEVELOPMENT OF GENERATOR

DIRECT CURRENT G-63 ( ) /G and G-67 ( ) /G

(HAND CRANKED)

CONTRACT DAAB07-70-C-0075

BY

R.S. BOVITZ

MAY 1972

Prepared by:

VARO INC. ELECTROKINETICS DIVISION
Santa Barbara, California

ECOM

UNITED STATES ARMY ELECTRONICS COMMAND · FORT MONMOUTH, N.J.

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13. ABSTRACT

The Generators, Direct Current, G-63( )/G and G-67( )/G developed under this contract encompasses the requirements of ECOM Technical Requirement SCL 7828, Ammendment 1.

Major component or subassembly areas involved with unit development may be classified as: Alternator and associated circuitry, mechanical drive, housing, and base assembly.

Electrical subsystem development was accomplished under Contract No. DA28-AMC-D1605 (E) and is presented in Technical Report ECOM 01605-F.

Mechanical drive development involved specifying a harmonic drive and designing a rugged handle and input shaft.

The housing was developed for minimum size and weight for containment of the alternator-drive subassembly and maximum acoustic noise suppression.

The mounting base assembly developed, includes consideration for universal functioning and prime factors of weight, strength and attachment.

Techniques were considered and implemented throughout the project to promote economical use of parts and fabrication processes. Use of standard parts and components where possible and joining major subassemblies such as housing and base components with the dip brazing process have been incorporated toward an economy which may become even more significant in mass production considerations.

Overall unit considerations resulted in an effort to integrate individual subsystem into an economical unit incorporating factors contibuting to operator efficiency for total operation and observation as encountered under field conditions.

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TECHNICAL REPORT ECOM - 0075-F

DEVELOPMENT OF GENERATORS

DIRECT CURRENT G-63 ( ) /G and G-67 ( ) /G

(HAND CRANKED)

FINAL REPORT

MAY 1972

REPORT NO. 1

CONTRACT NO. DAAB07-70-C-0075

POWER SOURCES DIVISION

DEPARTMENT OF THE ARMY TASK NO. IH6-64710 D 535 01-10

Prepared For:

U. S. Army Electronics Command
Fort Monmouth
New Jersey

Prepared By:

Varo Inc Electrokinetics Div.
Santa Barbara
California

ABSTRACT

The Generators, Direct Current, G-63( )/G and G-67( )/G developed under this Contract encompasses the requirements of ECOM Technical Requirement SCL 7828, Ammendment 1.

Major component or subassembly areas involved with unit development may be classified as: Alternator and associated circuitry, mechanical drive, housing, and base assembly.

Electrical subsystem development was accomplished under Contract No. DA28-043-AMC-01605 (E) and is presented in Technical Report ECOM 01605-F.

Mechanical drive development involved specifying a harmonic drive and designing a rugged handle and input shaft.

The housing was developed for minimum size and weight for containment of the alternator-drive subassembly and maximum acoustic noise suppression.

The mounting base assembly developed, includes consideration for universal functioning and prime factors of weight, strength and attachment.

Techniques were considered and implemented throughout the project to promote economical use of parts and fabrication processes. Use of standard parts and components where possible and joining major subassemblies such as housing and base components with the dip brazing process have been incorporated toward an economy which may become even more significant in mass production considerations.

Overall unit considerations resulted in an effort to integrate individual subsystem into an economical unit incorporating factors contributing to operator efficiency for total operation and observation as encountered under field conditions.

FOREWARD

The development of Generators, Direct Current, G-63( )/G and G-67( )/G (Hand Cranked) was performed for the U. S. Army Electronics Command, Fort Monmouth, New Jersey under Contract No. DAAB07-70-C-0075

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ILLUSTRATIONS

FINAL REPORT

1. DESCRIPTION

The development of Generators, Direct Current G-63( )/G and G-67( )/G has resulted in optimum, portable, light-weight, 30-watt generator units (~~Figure 1~~). The G-63 is capable of charging a 10 cell-12 volt nickel-cadmium battery and the G-67 is capable of charging a 20 cell-24 volt nickel-cadmium battery by hand cranking input with nominal effort within the limits of operator endurance. It encompasses maximum utilization of factors contributing to operating efficiency.

Basic design criteria were established by ECOM Technical Requirement SCL 7828 Ammendment 1, supplemented by information gained through customer liaison and the technical program under Contract No. DA28-043-AMC-01605 E. The object in achieving the optimum design was to satisfy the criteria established by defined and undefined design and operational requirements.

1.1 Description of Components

The design provides two major assemblies, the generator drive unit and the mounting base.

The generator drive unit consists of the following items:

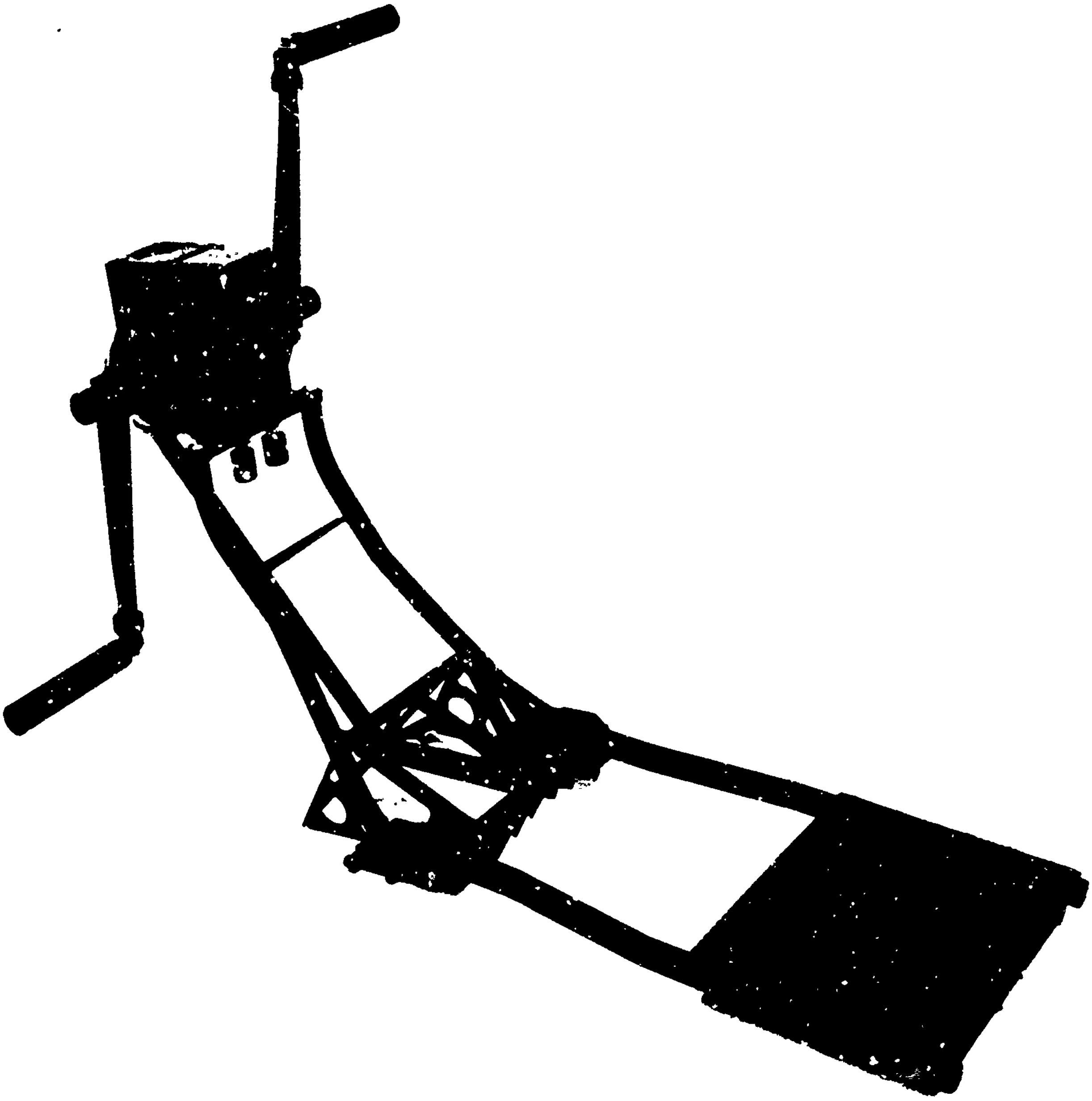
(1) 3 phase A.C. generator (alternator).
(2) Harmonic drive speed increaser.
(3) Multi-meter with external shunt.
(4) 3 phase bridge rectifier.
(5) Reverse polarity protection circuit.
(6) Opposing crank assemblies.
(7) 3 piece housing.
(8) Output electrical terminals.

The mounting base includes the following features:

(1) Neoprene rubber cushioned seat.
(2) Serrated type jaws for tree mounting when secured with belt assembly provided.
(3) Pivot seat for folding.
(4) Latch assembly for securing in folded configuration.

1.2 Description of Operation

Cranking the generator causes the input shaft and the harmonic drive flex spline to rotate at the input cranking speed. Since the harmonic drive concept requires the flex spline mate with the circular spline and since there are less teeth on the circular spline, the flex spline is elliptically deformed such that only teeth on two opposing sides of the flex spline engage the circular spline at any time. The member which deforms the flex spline is an annular ball bearing which is mounted upon an elliptically shaped mandrel. This member is the wave generator of the harmonic drive. Rotation of flex spline causes its teeth to engage the (rotationally fixed) circular spline in sequence thus causing flexure and rotation of the wave generator due to angular change of the elliptical shape of the deformed flex spline. The wave generator elliptical mandrel is attached to the alternator rotor shaft. This shaft is rotated at a rate of 100 times the input crank rate due to the ratio of teeth and flexure of the harmonic drive elements.



GENERATOR UNIT

FIGURE 1

The alternator rotor is a multipole permanent magnet which when rotated, in the distributed wound stator, causes a rotating electrical field in the stator. The stator windings produce a balanced 3-phase A.C. voltage of a frequency proportional to the rotor speed. This A.C. voltage is supplied to a 3-phase rectifier to produce the required D.C. voltage output.

2. DESIGN PROCEDURE

2.1 Initiation

Specification requirements and additional information inherently provided the guidelines leading to sequential component development. The basic alternator and associated electronics were identical to the unit developed under a previous contract. The design effort centered on a mechanical repackaging to produce a more rugged, lighter weight and quieter operating generator. The G-67 version used identical concepts to the G-63 but uses a higher voltage generator. Dummy loads simulating the required half discharged battery were used in the development. Having determined from the nominal alternator input requirements and the space envelope, the size of a specific harmonic drive unit (manufactured by United Shoe Machinery), was established and procured. Concurrent with optimization of the drive, the housing, handles and seat were designed and tested.

2.2 Alternator and Output Circuit

The alternator stator winding configuration and a 6-pole rotor were chosen operating at approximately 6,000 RPM (Figure 2).

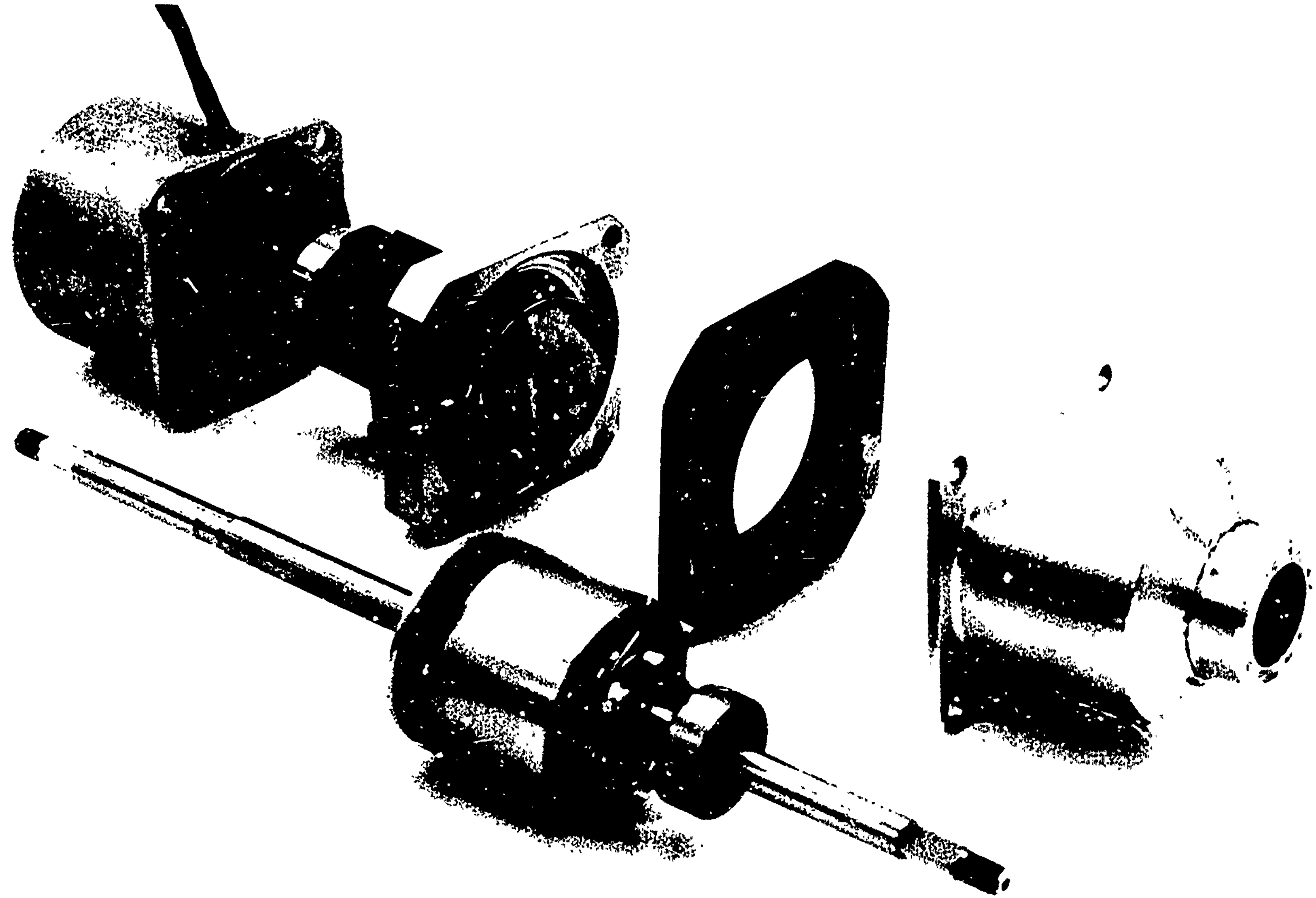
Alternator output is rectified to direct current through a full wave silicon diode bridge. Associated circuitry from the output of the rectifier to unit output terminals includes a combination voltmeter-ammeter controlled by an external switch selector for output monitoring and relay controlled reverse current protection of the meter. Selection of the meter was predicated by characteristics providing easy readability of output parameters supplemented by scale color coding for simple identification of operating ranges and rugged construction for maintaining operation after rough unit handling.

2.3 Harmonic Drive

A 100-to-1 ratio harmonic drive was selected to provide necessary power for rotor rotation. The harmonic drive could achieve the necessary efficiency at rated speed and torque -- allowing an overall efficiency in the range of 50%.

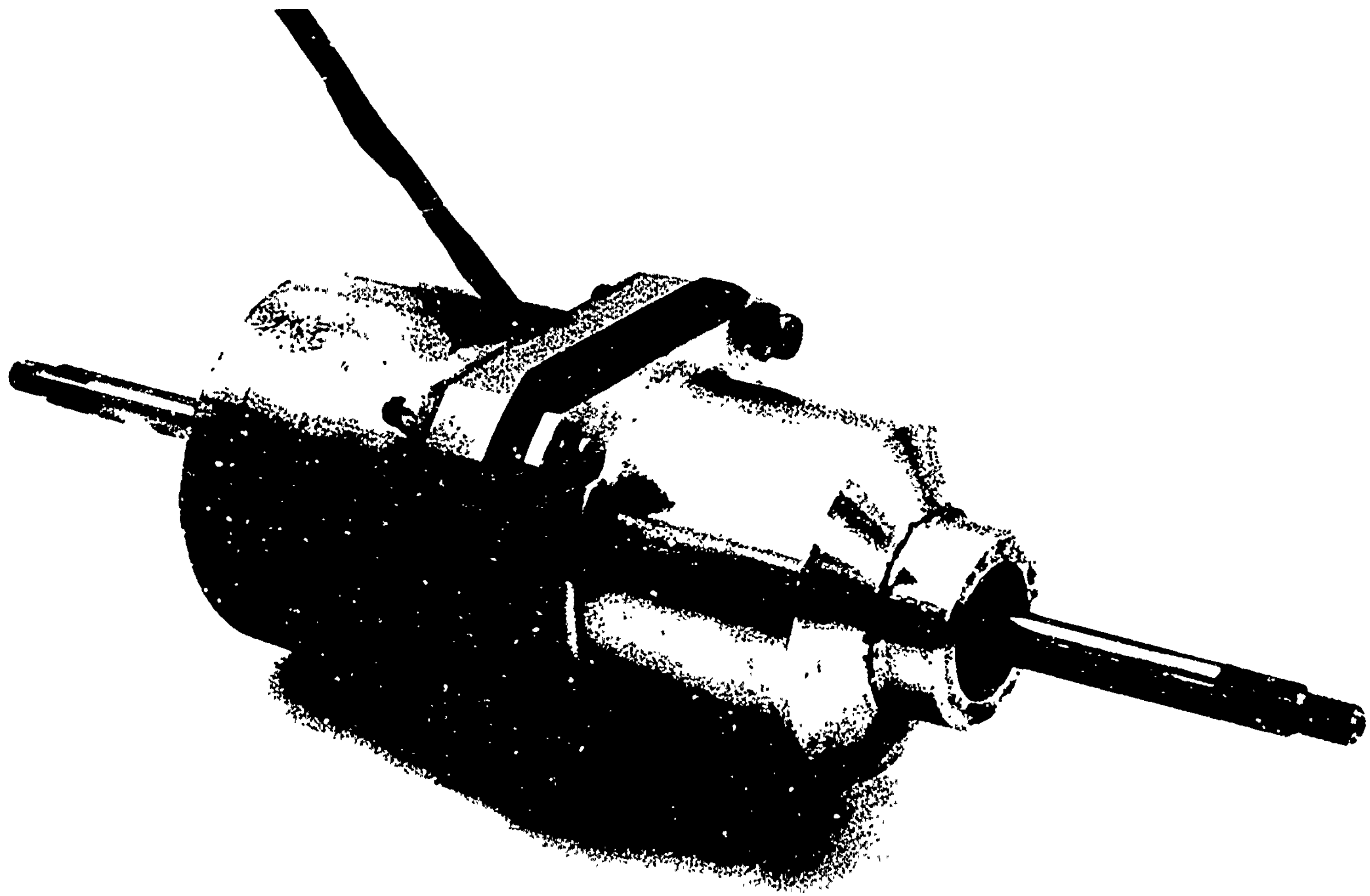
2.4 Housing (Figure 4)

A three-piece housing configuration provides minimum volume and weight configuration. The aluminum alloy parts are cast to achieve substantial weight reduction, economy of fabrication and strength. The housing is fabricated for minimum size required to contain the alternator-drive subassembly and associated circuitry. The center housing internally mounts electrical components by use of threaded studs, and externally mounts the combination voltmeter-ammeter and its control switch for monitoring charging characteristics. Placement of the monitor meter, switch selector and output terminals includes considerations for facilitating operation, ease of observation, identification, and protection from adverse effects during handling.



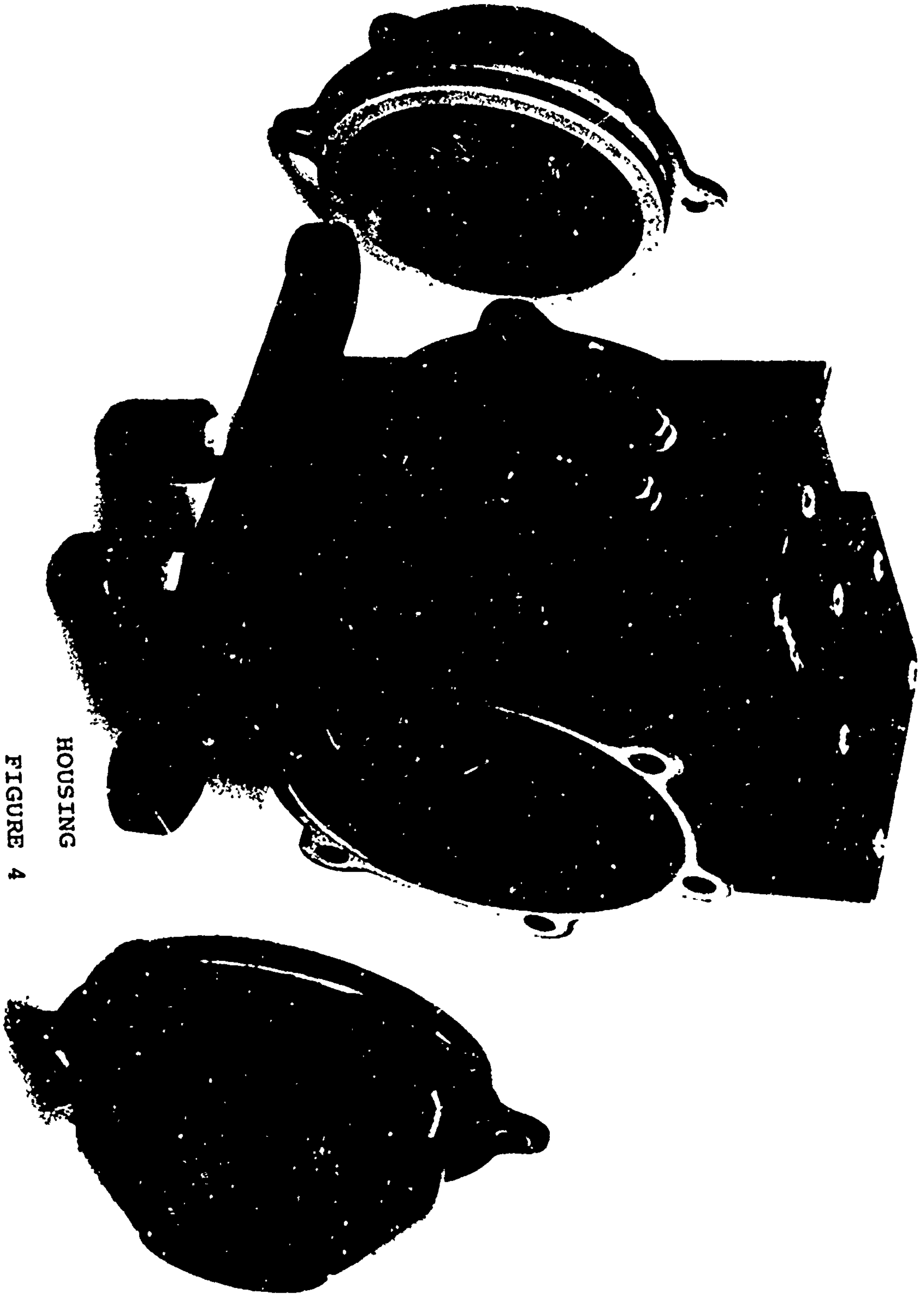
ALTERNATOR & HARMONIC
DRIVE COMPONENTS

FIGURE 2



ALTERNATOR-DRIVE SUB-ASSEMBLY

FIGURE 3



HOUSING
FIGURE 4

2.5 Base

The base includes integral mounting jaws for gripping and which are spaced for mounting rigidity. Seat and belt attachment points are provided to allow the generator to be operated on the ground in a sitting or kneeling position, or when attached to random objects, preferably trees or posts. The base holding arrangement utilizes the nylon belt with attached tightening clamp assembly to secure the base in place. The seat is cushioned for operator comfort with a neoprene rubber coating.

2.6 Crank Assembly

A folding crank assembly with friction reducing roller grip is connected to each end of the shaft protruding through openings provided in each end of the housing sections. The handles are forged elements for maximum strength/weight ratio. When in the unfolded or operating position, the crank handles are 180° out of phase to provide a more balanced continuous cranking motion. A cranking radius of six inches provides sufficient leverage for input power in relation to arm motion required. This, combined with crank operating plane separation, negates possible interference between crank handle and proximate objects to which the total unit may be attached. Mounting hubs provide an interface between the crank and drive shaft by self-locking screw attachment. The hubs serve as pivot points for the cranks to maintain the required relative position with the drive shaft. Integral with each crank is a slotted jaw which captures the end of the drive shaft at a point providing flat locking surfaces when the handles are folded to the operating position. The handles fold 180° toward the center housing and are rotated against the base structure for storage when the generator is not in use. This provides protection for the handles and a more compact package during transport. The folded handles are cradled in position by the seat when it is latched in place, thereby forming a compact package for carrying or shipping.

2.7 Results

Operational tests were performed on the final complete generator unit design to insure compliance with overall specification requirements. No major problems were encountered during the development.

2.7.1 Electromagnetic Compatibility

One generator was tested per the requirements of MIL-STD-461 Class IIIB using the procedures specified in MIL-STD-462 and found acceptable.

2.7.2 Air Seal Test

The generator end bells were unbolted and the end bell pulled back to break the o-ring seal. The end bells were then returned to the assembled condition and the entire generator package subjected to a vacuum of 1 psig applied to the interior of the generator through the part provided. The vacuum was sealed off and the generator interior pressure measured during the ensuing period of 1 minute.

The decrease in vacuum did not exceed 0.01 pounds per square inch gage (psig) per minute for the one minute.

2.7.3 Rated Output Test

With the generator connected to a resistive load of 7.5 $\pm$ .07 and cranked at a speed of 60 $\pm$ 2 RPM ohms the output current was measured with an external ammeter (1/2% accuracy) and was between 2.0 $\pm$ .1 amperes.

During the test the generator switch was in the current position and the accuracy of the meter compared with an external ammeter. The generator meter did not deviate from the external meter more than ± 4.5% (± .09 amperes).

2.7.4 Output Voltage Test

The output voltage of a G-63 generator was measured when connected to a resistance load (variable) and cranked at speed of 50, 60, 80 RPM ± 2 RPM. The load was adjusted to maintain an output current of 2.0 ± .1 amperes. The voltage and current into load was measured with an external voltmeter and ammeter. As measured with the external voltmeter, the output voltage was between 15 ± .5 volts DC at 60 RPM and within the range of 12 to 22 volts DC over the cranking speed range. During this test the switch on the generator was adjusted for voltage measurement and the accuracy of the generator meter determined by comparison with the external voltmeter (1/2%). The difference between the voltage readings did not exceed 4.5%.

2.7.5 · ficiency Test

 ie efficiency of the G-63 generator was easured as follows: The generator was mounted to swing freely on the crankshaft. A beam with an effective lever arm exactly 6 inches long measured to the center of the crankshaft, and at right angles to the side of the generator, was attached to that side of the generator so that the beam was in a horizontal position.The generator was

operated under rated load (7.5 ohms) and at a speed of 60 RPM $\pm$ 2. The vertical restraining force at the end of the beam required to maintain the beam in a horizontal position was measured.

The percent efficiency of the generator was calculated as follows:

$$\frac{7.04 \times W}{FN} \times 100 = \%\ \text{Efficiency}$$

Where:

W = Watts Output of Generator

F = Pounds restraining force required to prevent rotation (foot pounds)

N = Rev. per minute

7.04 = Constant

The generator exhibited an efficiency greater than 50%.

The test was repeated for a G-67 generator except the load was 30.0 ohms. The generator exhibited an efficiency greater than 50%.

2.7.6 Overload Test

The G-63 generator was driven at a cranking speed 110 $^{+5}_{-0}$ RPM with a variable resistance load across the output to obtain a current of 3.0 $\pm$ 0 1 amperes. This condition was maintained for one (1) minute. The load was removed and a five (5) minute rest period was observed. This cycle was repeated ten (10) times. The generator showed no evidence of failure, and met the requirement for rated output of 2.0 $\pm$ .1 amperes and an overall efficiency of not less than 50% when operated at 60 RPM.

The test was repeated for a G-67 generator except the current was 2.0 ± .05 amperes during the overload test and 1.0 ± .05 amperes for rated output. The generator exhibited an efficiency greater than 50% at rated output.

2.7.7 Reverse Current Test

A DC power supply with an adjustable output from 0-25 VDC was connected to the output terminals of the G-63 generator in correct polarity (plus on power supply connected to plus on generator, minus to minus). Also connected was a fused 0-1 ma ammeter in the circuit. The meter switch was in the "current" position. The power supply voltage was increased to 25 VDC. The leakage current did not exceed 0.5 ma in the correct polarity connection.

The polarity of the power supply connection to generator was reversed. The leakage current did not exceed 150 ma in the reverse condition from 0 to 25 VDC. The generator showed no physical or electrical damage.

The tests were repeated except the voltage was adjusted from 0 to 50 VDC for each leakage current determination with a G-67 generator. The leakage current did not exceed 150 ma and the generator showed no physical or electrical damage.

2.7.8 Protection Test

The generator was cranked at speed of 60 RPM ± 2 at a rated load (7.5 ohms). A short circuit was momentarily applied across the terminals a minimum of five (5) times, with one (1) minute between cycles.

One generator failed upon application of the fifth short circuit. The harmonic drive suffered a fracture of the flex spline. Evaluation of the failure resulted in reaching the conclusion that the flex spline failure was a random one and was caused by overstressing the flex spline with the mechanical drive.

As the drive was a "hard" drive, the sudden shock of a short circuit to the generator far exceeded the rating of the flex spline. The drive was modified utilizing a spring clamping system to reduce the shock loading and subsequent retests were successful.

The same test was applied to a G-67 generator, and the unit passed successfully,

Immersion Test

The generator was subjected to the test of Method 512, Procedure I of MIL-STD-810 as follows:

A container was filled with water capable of submersing the generator assembly 36 $^{+5}_{-0}$ inches from the surface of the water.

The water was maintained at a temperature of 18° ± 5°C (64°F) and the temperature of the generator at 27° ± 3°C (49°F) above the temperature of the water. For example, the actual water temperature was 62°F (17°C) the generator temperature was (17 + 27) ± 3°C (41°-47°C) which was (106°F to 117°F) prior to immersion in the water.

The generator was to remain for 120 ± 5 minutes (2 hrs. ± 5 min.).

The generator was removed from the water and wiped dry. The end bells were opened and examined and there was no evidence of water leakage.

2.7.10 Acoustic Noise Test

The acoustic noise due to operation of the generator was measured with a sound level meter (Type 1551-B, General Radio or equal) with B weighting (70 db) and A weighting (40 db) in an open area. These measurements were made at a distance of three (3) feet from the top front edge of the generator to the center of the sound level meter microphone and with the generator mounted for operation both on the ground and mounted to a fixed object (tree or post). With the generator operating at 60 $\pm$ 2 RPM under rated load (G-63 rated load is 7.5 Ω) (G-67 rated load is 30.0 Ω) the acoustic noise level of the generator did not exceed 57 db at (B) weighting or 54 at (2) weighting.

2.7.11 High Temperature

The generator was tested in accordance with MIL-STD-810, Method .31, Procedure II high operating temperature of 155°F.

The generator operated successfully with no damage resulting from the test.

2.7.12 Low Temperature

The generator was tested in accordance with MIL-STD-810, Method I, Procedure I. The storage temperature was -65°F and the low operating temperature was -50°F.

2.7.13 Humidity

The generator was tested successfully in accordance with MIL-STD-810, Method 507, Procedure III.

2.7.14 Altitude

The generator was tested successfully in accordance with MIL-STD-810, Method 500, Procedure I.

2.7.15 Sand and Dust

The generator was tested successfully in accordance with MIL-STD-810, Method 510, Procedure I.

2.7.16 Salt Atmosphere

The generator was tested successfully in accordance with MIL-STD-810, Method 509, Procedure I.

2.7.17 Fungus

The generator was tested in accordance with MIL-STD-810, Method 508, Procedure I.

Some evidence of fungus was noted on the seat and the military approved output terminal caps. A retest was made on the seat assembly which was re-manufactured using anti-fungus rubber material, and two new output post rubber covers which are military approved. The seat showed no fungus growth and only a small colony was noted in the top of the rubber covers.

2.7.18 Resonance Search

The generator was tested in accordance with MIL-STD-810, Method 514, Procedure IX, Part I.

The generator did not have any resonances in the frequency range of 10-55 cps that exceed twice the amplitude of the applied vibration.

2.7.19 Bounce

The generator was tested successfully in accordance with MIL-STD-810, Method 514, Procedure XI, Part 2, except the locknut on one handle grip came loose. However, the generator operated satisfactorily after the bounce test.

2.7.20 Drop

The generator was tested successfully in accordance with MIL-STD-810, Method 516, Procedure II. However, in operation, a small crack appeared in the left front tripod adjacent to the weld area.

2.7.21 Bench Handling

The generator was tested successfully in accordance with MIL-STD-810, Method 510, Procedure I.

2.7.22 Lubrication Design Modification

A failure of substantial magnitude was encountered during the test sequence that immediately preceded the commencement of the reliability test program. Prior to the failure, all 12 units scheduled for the reliability testing had been operated for a total of 12 hours ON time, continuous

with a duty cycle of 5 minutes ON, 1 minute OFF. Subsequent to this burn-in, a thermal survey of approximately three hours duration was conducted in the temperature chamber at a temperature of 104 degrees with an operating speed of 56.6 RPM.

Two configurations of redesigned harmonic drives were fabricated

Configuration 1 -- Oil impregnation of the phenolic separator to provide lubrication for the bearing until the grease cartridge bleeds lubricant into the bearing.

Configuration 2 -- Use of a lubrication method developed by Ball Bros. Research Corporation called "Vac Kote".

The five (5) units modified to configuration 1 fully passed 100 hours of testing under the operating conditions required by the reliability test (duty cycle of -5 mins ON and 1 min OFF, temperature 104°F).

Three (3) units modified to configuration 2 were subjected to the reliability test. Two of the three units failed in less than 48 hours. The test was then discontinued to prevent damage to the third unit.

Based on this data it was established that configuration 1 represented the optimum design of the harmonic drive. Thirty-six (36) G-63 & G-67 Hand-Cranked generators were disassembled and the harmonic drives were returned to USM for up-grading to configuration 1. The results of the 12-hour burn-in required by the approved reliability test plan of the new configuration was as follows:

A. One unit failed after 2 hours.

B. The second unit failed after 6 hours.

C. A third unit failed after 11 hours.

The burn-in test was discontinued.

The failure analysis of all three (3) units was attributed to the lack of lubrication in the wave generator bearing.

Apparently the amount of lubrication in the bearing becomes insufficient before the lubrication cartridge begins to supply the additionally required lubricants to the bearing. The lubrication in the bearing heats up as a result of the friction and eventually becomes carbonized, losing its ability to lubricate which results in the premature failure.

The corrective action was to provide a supply of lubrication to the bearing, by packing the space between the bearing and the porous sleeve with additional grease. The entire lot of production generators were reworked and submitted to reliability tests which had successful results.

2.8 Reliability Test Results

The testing was performed in accordance with the Varo Reliability Test, Demonstration and Evaluation Plan, Reliability Demonstration Test Procedure, written in accordance with MIL-STD-781B and SCL 7828A, paragraph 4.9.

Twelve D.C. Handcranked Generators were subjected to testing at 60 $\pm$ 5 RPM, 30 watts nominal output (standard load resistors used) at an ambient temperature of 40 $\pm$ 5°C utilizing a duty cycle of five (5 $\pm$ 1/4) minutes "ON" and one (1 $\pm$ 1/4) minute "OFF".

The testing was performed at the VARO INC. Reliability Test Facility, Santa Barbara, California.

Twelve units completed 261 hours each of official testing per an approved test procedure.

Five (5) of the twelve (12) units in addition to the 261 hours, received an additional 159 hours of testing under the same conditions. 100 of the additional hours were completed before the official testing was started in conjunction with the evaluation of the harmonic drive lubrication condition finally utilized. The balance of 59 hours was conducted at the conclusion of the official 261 hours of testing.

This gives an accumulated total test time on five (5) units of 420 hours/unit which was agreed upon as a condition for approval of the Reliability Test Plan by Fort Monmouth personnel.

Detailed test procedures, test equipment utilized, and all other facets of the reliability test methods are given in the VARO Report, No. QCR 004 titled 'Final Reliability Test Report'.

2.8.1 Failure Analyses

At the conclusion of 184 hours of "ON" time which is the 1st acceptance point on the test plan acceptance line, the twelve units were stopped, removed from the test stand and a Group A acceptance test was performed on each unit. Model G-67 Serial Number 6 failed to satisfy the requirements of paragraph 4.7.2.5 of SCL 7828A. With 50 VDC applied to the output terminals in the correct polarity, a leakage current of 2.5 ma was measured. The specification limit is 0.5 ma maximum. All other measurements were within specification.

The failure was traced to a diode in the meter shunt package, Part Number JAN IN4246. This diode, when isolated, exhibited the 2.5 ma leakage current in the reverse direction. This diode has been returned to the manufacturer for formal failure analysis (Micro-Semiconductor). Due to the nature of the failure and the proven high reliability of JAN components, this leakage is considered a random failure. It was a relevant failure for purposes of the reliability test acceptance. Due to this failure, Serial Number 6 was repaired by replacing the diode and all twelve generators were placed back on the test stand and the test restarted.

On 11 June 1971, 07:40 hours, during a routine voltage-current measurement the test technician inadvertantly plugged the ammeter plug jack into the voltage socket on the test stand.

This caused an immediate short circuit across the generator in which the voltage selector rotary switch was positioned due to the low impedance of the ammeter. By studying the circuit diagram in the Reliability Test Plan it can be seen that if a direct short circuit such as the ammeter supplied was substituted for the voltmeter, a short circuit would be applied to the generator in which the rotary switch was positioned. The technician was thinking he had the voltmeter plugged in and didn't see a voltage reading on the voltmeter scale. Since the last generator to be checked during the normal voltage check was position 12, the rotary switch was in this position at that time. The technician proceeded to turn the rotary switch through positions 1, 2, 3, 4, 5, and 6 searching for a voltage reading before he realized what had occurred. At this point he opened the temperature chamber and noticed that the shear pins on the drive stand had sheared on positions 1, 2, and 3. These pins were a mild steel pin which shears very close to the start up torque. The other positions short circuited had slightly harder steel pins to replace the soft mild steel pins which were originally installed but sheared upon start up. This is understandable when one considers the normal variation in start up torque and efficiencies. The primary purpose of the shear pins in the drive system was to protect the crankshaft from breakage if the harmonic drive locked up during test. This occurs at a torque much higher than the short circuit torque level.

It is necessary to understand the above described sequence of events to understand the voltage changes which took place in generator positions 12, 4, 5, and 6.

A review of the data before and after the short circuit on positions 1, 2, and 3 indicates no shift in output voltage or current. This is because the shear shafts failed and the generator stopped under the normal short circuit condition. A review of the data for positions 12, 4, 5, and 6 indicates a drop in current and voltage of up to 1.5 volts and 0.05 amps. Although the generator is designed to withstand a full load short circuit, the normal condition under hand cranking operation is for the generator to become extremely difficult to crank under a suddenly applied short circuit. This was not the case in the reliability test. The generators were driven by a 1-1/2 horsepower motor through a gearbox and set of speed reducing timing belts and sprockets.

Under these conditions the speed did not drop during the short circuit as was normal during the acceptance testing or would be normal during handcranked operation. The short circuit applied to positions 12, 4, 5, and 6 is therefore, considered overly severe and not the same condition required by SCL 7828A. The change in voltage is therefore caused by the excessive short circuit condition and is not considered a failure condition. This situation was discussed with the Fort Monmouth technical personnel and approval to continue testing was granted. The test was continued to the 184 hour acceptance point without any appreciable additional change in output

voltage or current. Slight changes in voltage and current are due to speed fluctuations and load resistor temperatures and are normal. No voltage decline trend was noticed. This was not considered a relevant failure for Reliability Test Evaluation purposes.

2.8.2 The test was completed on twelve (12) generators with 261 hours per generator for a total test time of 3132 hours. This represents an acceptance decision of the reliability testing in accordance with MIL-STD-781B, Test Plan IV. One (1) relevant and one (1) non-relevant failure occurred, see FAR 01 and FAR 02.

The testing was in accordance with the specified requirements, with the exception of the 96 hour "ON", 8 hour "OFF" secondary duty cycle. The test was conducted continuously except when test stand maintenance required a shut down, and repair of the facility was required, or when a potential failure condition was being analyzed. Due to the total "OFF" hours for these reasons exceeding the 8 hours specified rest period every 96 hours, this rest was not conducted as had been planned.

2.9 Maintainability

Incorporated in the overall generator design are features to facilitate ease of maintenance. This has been achieved by use of,and placement of, components for accessibility in the event that trouble shooting is required. The total unit may be disassembled and assembled with standard tools such as screw driver, pliers, and solering iron, or improvised tools if necessary. Electrical component trouble shooting is facilitated after disassembly of the housing by clear access to all internal electrical connections for test equipment readout.

2.10 Conclusions and Recommendations

The developed units comply to the specification and did not degrade during qualification testing; therefore, it is concluded that the units should perform under service conditions.

APPENDICES

Information contained in the Appendices describe in detail major development areas associated with the generator, direct current, G-63( )/G and G-67( )/G.

APPENDIX 1

ELECTRICAL SUBSYSTEM

Total source of electrical power for both output and control circuits is generated in a 6-pole, 3-phase, permanent magnet alternator. D.C. Voltage at the level required for a 30-watt load is obtained by conversion of the alternator output through a 3-phase full wave silicon rectifier bridge.

Reference to the electrical schematic, outlined on Figure 5, shows the generator, rectifier, and metering circuits to be protected by two relays. K1 relay is energized through a half wave silicon rectifier CR2 which is in series with one phase of the alternator winding. This relay, with contacts normally open, isolates the generator from the system until approximately 75% of minimum cranking speed is achieved. At this point the supply is transferred to the main output terminals through the normally closed contacts of K2 relay. Simultaneously, energy is supplied to the voltage sensing portion of the metering circuit, and with the change-over switch SW1 in the "voltage" position, read-out of the terminal voltage is displayed on the voltage scale of the meter when the cranking speed has reached sufficient value to generate a minimum of 10 vdc or 20 vdc for the G-63 or G-67 respectively. The voltage sensing portion of the meter is contained between terminals 3-4 of the meter circuit which provides protection to the meter by a blocking diode in the event of reverse connection of the battery to the main output terminals.

In addition to the meter, the alternator and rectifier are protected against reverse connection of the battery by K2 relay. The relay coil is connected directly across the output terminals through a blocking diode CR3. If the battery should be reverse connected, it will energize the relay, whose contacts will open, and isolate the battery from the generator.

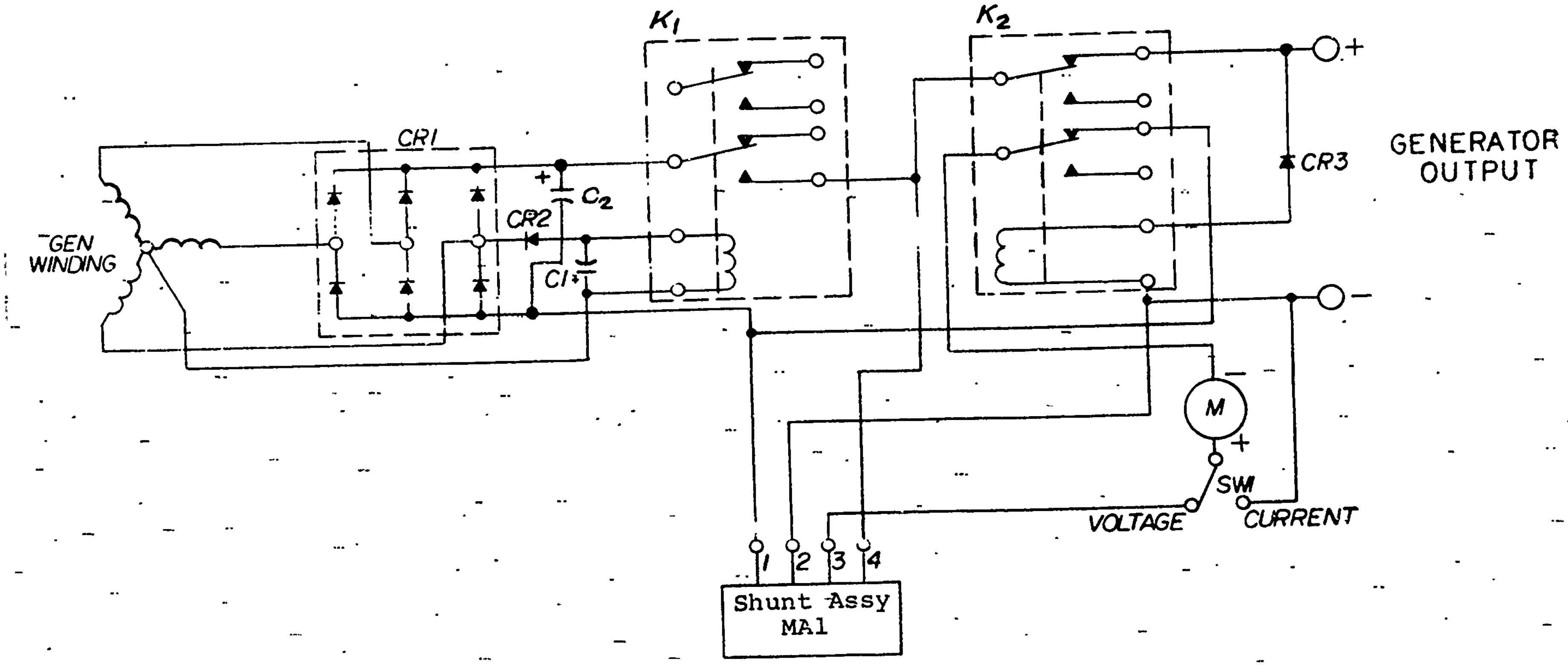


FIGURE -5

HAND CRANK GENERATOR SCHEMATIC

Under normal operation, the charging rate can be determined by placing the meter switch SW1 in the "current" position. This puts the meter coil in parallel with the meter shunt connected across terminals 1-2 in the meter circuit. Read-out of the charging rate is displayed on the inner scale of the meter which is divided into three different colored graduations, white, green, and red. The charging rate is adjusted to the desired value by varying the cranking speed.

APPENDIX 2

MECHANICAL DRIVE & HOUSING

The mechanical power transmission system providing alternator input is the United Shoe Machinery Corporation harmonic drive, consisting of a flex spline, circular spline, and wave generator. The type of drive was specified in the specification.

Configuration

Preliminary design and alternator determination resulted in the basic mounting geometry dictated by the drive system. The drive system, devised to allow minimum volume for components required, resulted in a main drive shaft for harmonic drive circular spline input power about which rotates a counter shaft mounting to the alternator rotor.

Appropriate relationship is achieved by complimentary precision ball bearing supports.

Lubrication

A major design problem was to provide a sufficient amount of lubrication of the spline to meet 500 hours of operating life. After some development it was determined that the grease must be packed between the grease holder and the ball bearing to insure that oil will adequately bleed from the grease holder to the ball bearing.

Reliability Test

Subjecting the G-63 and G-67 generator units to a 500-hour life testing per SCL 7828 Amendment 1 resulted in some failures of the wave generator bearing caused by the inadequate lubrication method. The addition of the grease bridge between the grease holder and bearing solved that problem.

APPENDIX 3

MATERIAL APPLICATIONS

Constant consideration has been given throughout the G-63 and G-67 generator development toward utilization of materials, components, and processes that contribute to overall weight reduction and processing efficiency without reducing performance and handling capabilities.

Incorporating tubular and sheet metal aluminum alloy parts jointed by the dip brazing process for the base and housing components,resulted in minimum weight with good strength characteristics. The joining process can be an economy factor for higher volume production consideration. One drawback to this type of construction is the limited vibration damping ability which requires the supplementary use of damping compounds. Multiple functions have been incorporated in regard to placement of components, such as meter, switch, output terminals and mounting of major subassemblies, so that protection and operability are afforded with minimum increase of material.

Corrosion resistant materials or standard parts and fittings processed for corrosion resistance have been incorporated where practical in the design.